External Monitoring of Endpoint Configuration Compliance

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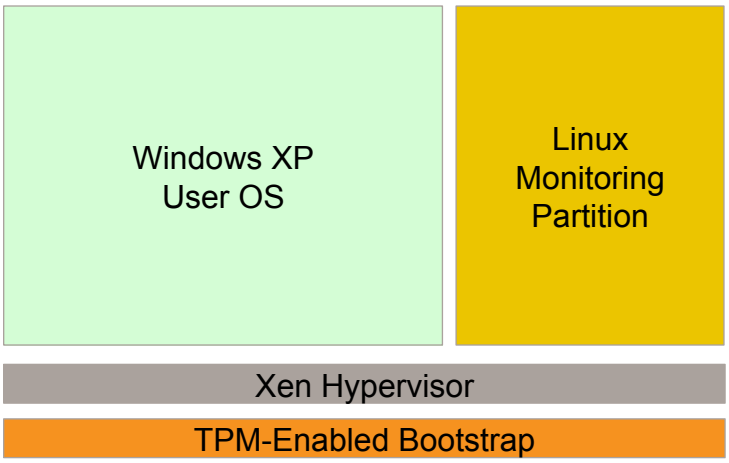
EC-CAM Overview

- *Enterprise Configuration Compliance Administration Manager*
  - Assess the overall enterprise risk
  - Focus on configuration compliance
  - Ensure that systems meet policy
  - Not equivalent to real-time blocking
- Compliance from inside the OS is difficult
  - Traditional agents execute in the context of the OS they monitor
  - Rootkits can create a *hall of mirrors*
- The EC-CAM Agent
  - Take advantage of virtualization hardware and software
  - Observe each system from outside a virtual machine
  - Much harder to spoof, emulate, or circumvent

The Semantic Gap

- Virtualization introduces a *semantic gap*
  - Policy is expressed in high-level constructs
  - Enforcement occurs at low-level interfaces
- We have perfect visibility into the Virtual Machine
  - Very high confidence that the bits and bytes are reported accurately
  - How confident are we that we know what they mean?
- Alternately
  - We are not dependent on untrustworthy OS APIs
  - But we can no longer depend on OS APIs

Endpoint Architecture



Analysis Overview

- Analysis
  - Pause the virtual machine (e.g., nightly check)
  - Inputs: raw memory, swapfile, file system
- Periodic checks
  - Executables in file system
  - Registry settings
  - Running process code
  - *Adding* stored CPU state
- Real-time checks
  - Monitor hardware changes

Checking the File System

- File system compliance
  - Are any disallowed or unknown applications present on disk?
  - Disk may be virtualized or raw block device
- Process
  - ntfs-3g presents raw disk as a *read-only* file system
  - Walk the file system, looking for Portable Executable (PE) headers
  - Hash contents of PE files
  - Check hashes against a whitelist of allowable applications

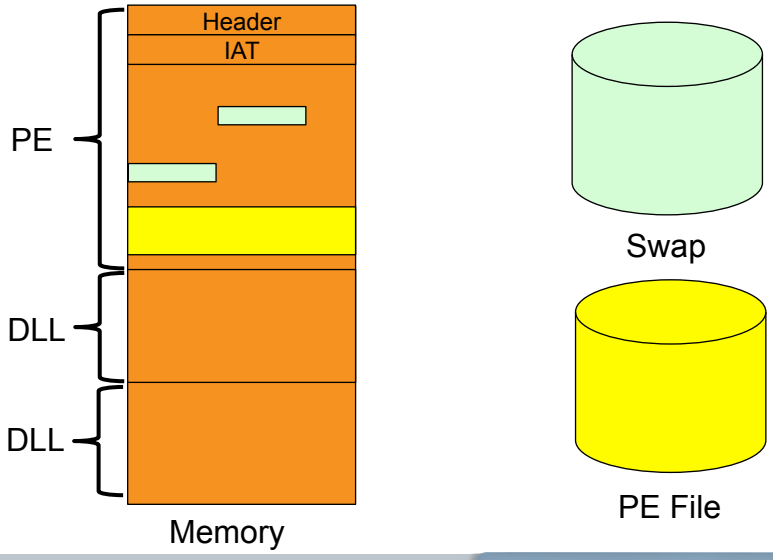
Checking the Registry

- Windows Registry compliance
  - System and application configuration database
  - Stored in undocumented “hive” files
  - Accessed exclusively through APIs (inaccessible to us)
- Process
  - Access the registry hive files through ntfs-3g
  - Use ntreg library to get read-only access
  - Examine specific security-relevant keys, installed software

Checking Running Processes

- Running Process compliance
  - Are necessary security applications running?
  - Are any unknown or disallowed programs running?
  - Do any running programs or drivers show signs of tampering?
- Process
  - Modified Xen *dump-core* creates flat file of VM memory image
  - ntfs-g provides access to swap file, program files
  - Check that each executing program is consistent with disk image
  - Report hashes of executing programs

Checking a Running Process



Observations: Consistency

- Concern about accessing memory/files beneath APIs
  - Structural integrity
  - Uncommitted cache data
- Integrity has not been a problem
  - The Windows registry is (now) quite resilient
  - Memory structures are fairly stable
  - Tools have proven fairly robust
- Uncommitted changes have also not been a problem
  - Disk changes settle fairly quickly
  - Compliance-relevant changes are rare
  - Worst case, changes will be detected in the next pass

Other Observations

- Windows XP
  - Trial and error ("Operationally specified")
  - Some compatibility issues across Service Pack versions
  - No hotfix has broken any of our code
- Generality
  - Successfully applied to VMware Workstation & Fusion snapshots
  - Should be applicable to hibernated system
- False Positives
  - Legitimate modifications to NTOSKRNL, HAL
  - Changes to several Microsoft DLL

Related Work

- Virtual Machine Introspection
  - Garfinkel and Rosenblum, *A Virtual Machine Introspection Based Architecture for Intrusion Detection*, 2003
  - Jiang, Wang, and Xu, *Stealthy Malware Detection through VMM-based "Out-of-the-Box" Semantic View Reconstruction*, 2007
  - Litty, Lagar-Cavilla, and Lie, *Hypervisor Support for Identifying Covertly Executing Binaries*, 2008
- Memory forensics
  - Kornblum, *Using Every Part of the Buffalo in Windows Memory Analysis*, 2007
- Rootkit detection
  - Rutkowska, *System Virginity Verifier*, 2005

Discussion

- Malware advances
  - We have observed malware unlink itself from process lists
  - Could malware construct shadow copies of Windows data structures
  - Could it “unlink” an entire core?
- Live Forensics
  - Most Windows structures appear fairly stable
  - Could sufficiently resilient code work without pausing the OS?
  - Preliminary experimentation has been promising
- JIT Compilers / Interpreters
  - How to distinguish inserted code from JIT-compiled code?
  - What are the implications of whitelisting an interpreter?

Confidence in a connected world.

Thank You!

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